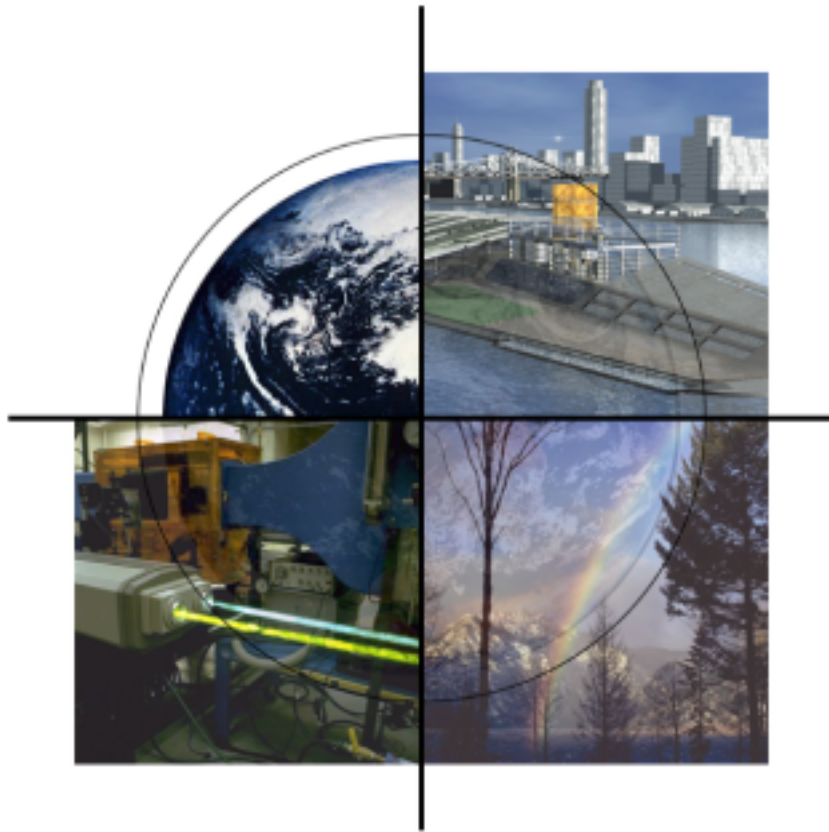


Opportunities and Challenges for New Clean Coal Technologies



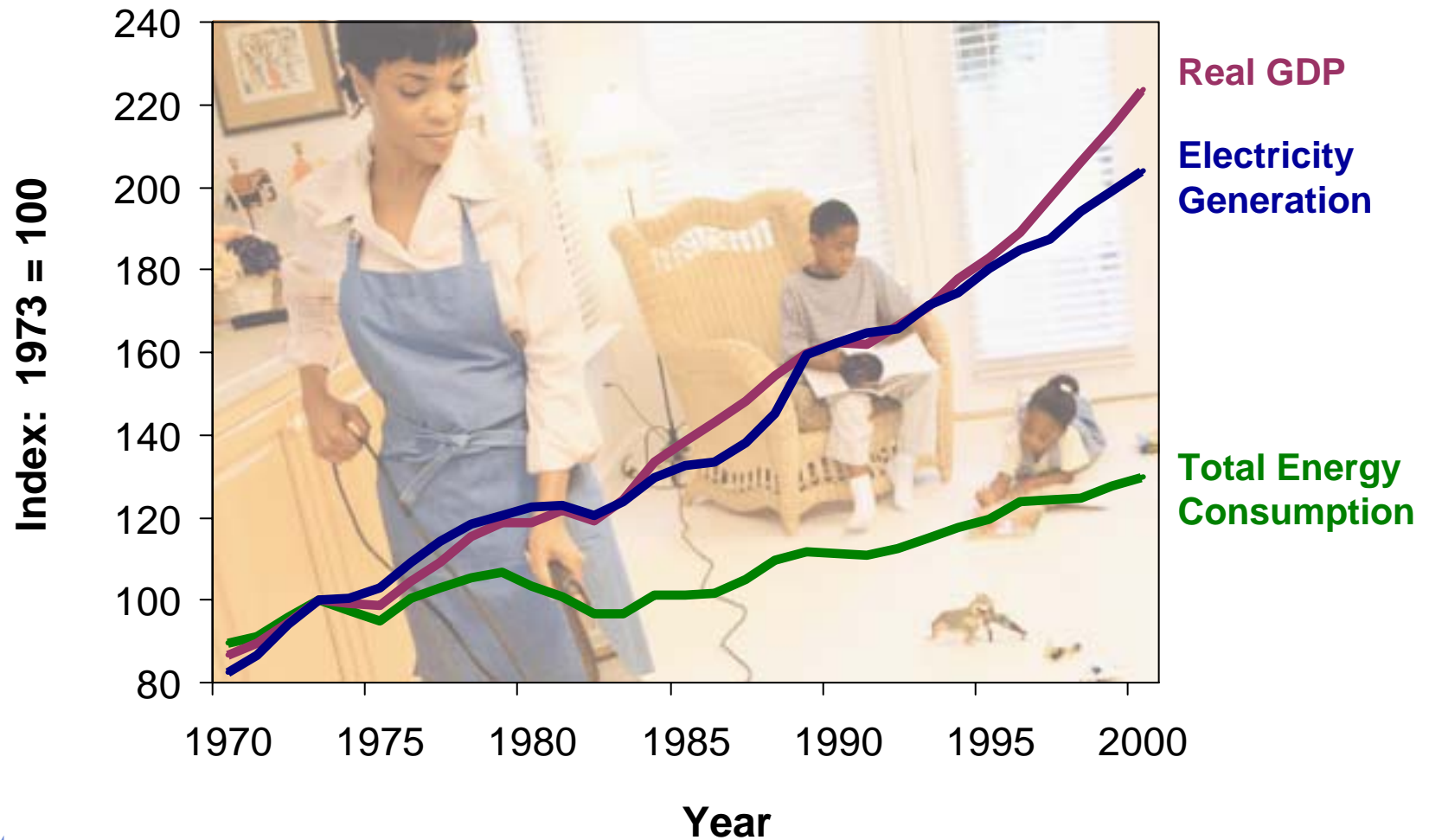
*Presented by
Mike Eastman, Manager
Clean Coal Technology
Demonstrations
at
Fairmont State College
Robert L. Carroll Lecture*

October 23, 2003

National Energy Technology Laboratory

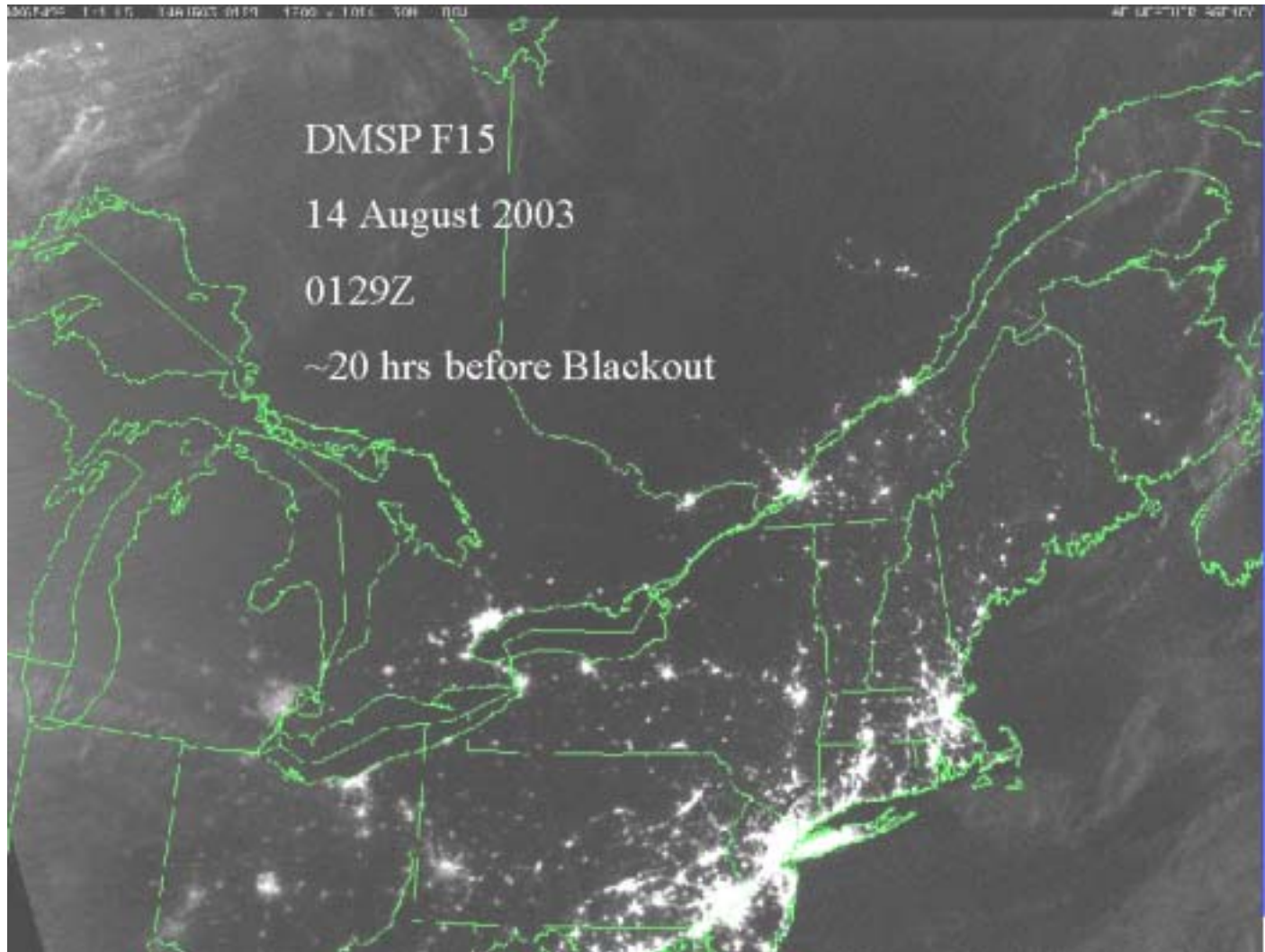


Economic Growth Linked to Electricity



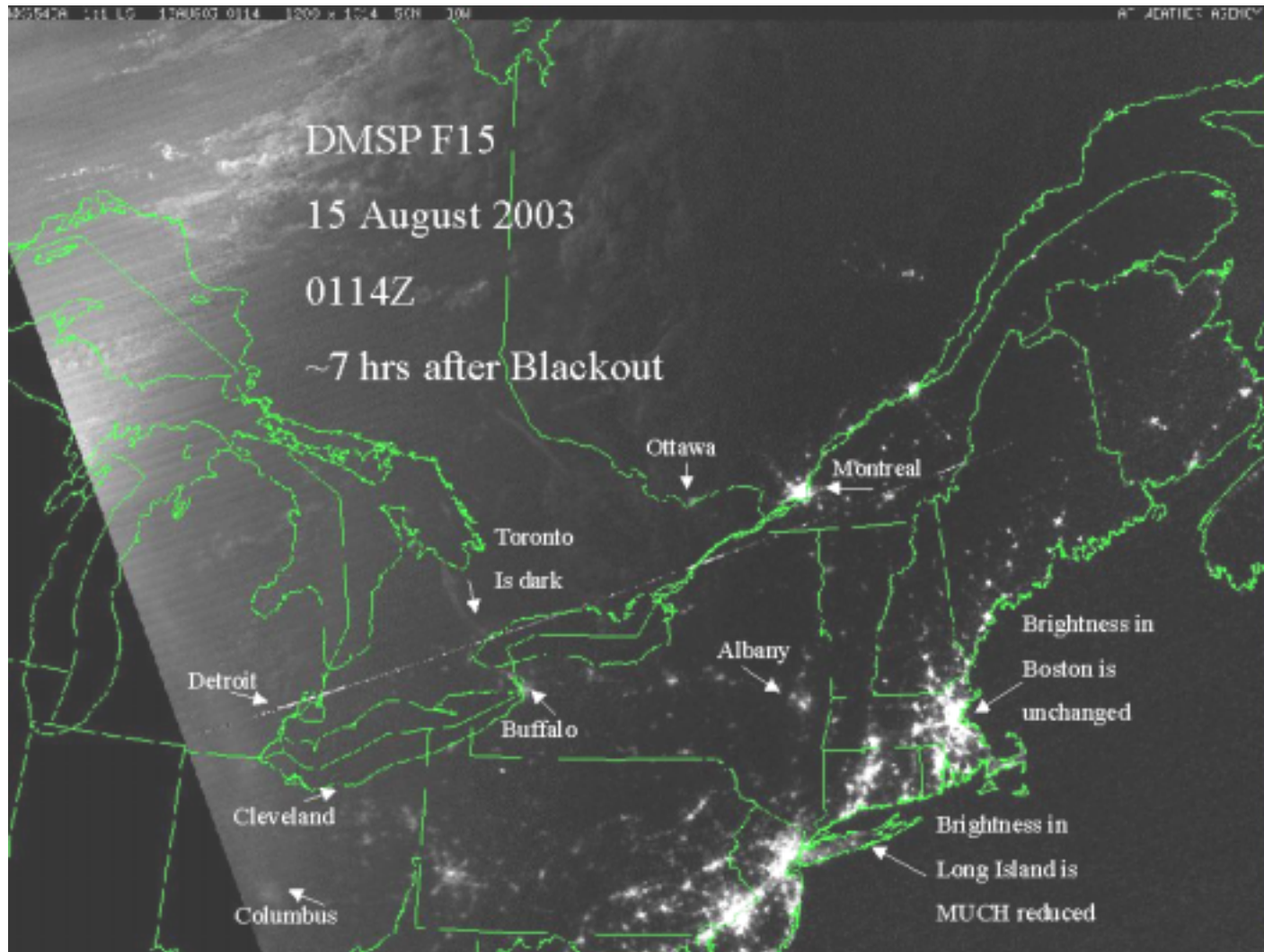
2003 Electric Power Blackout (before)

(photos courtesy of NOAA)



2003 Electric Power Blackout (after)

(photos courtesy of NOAA)



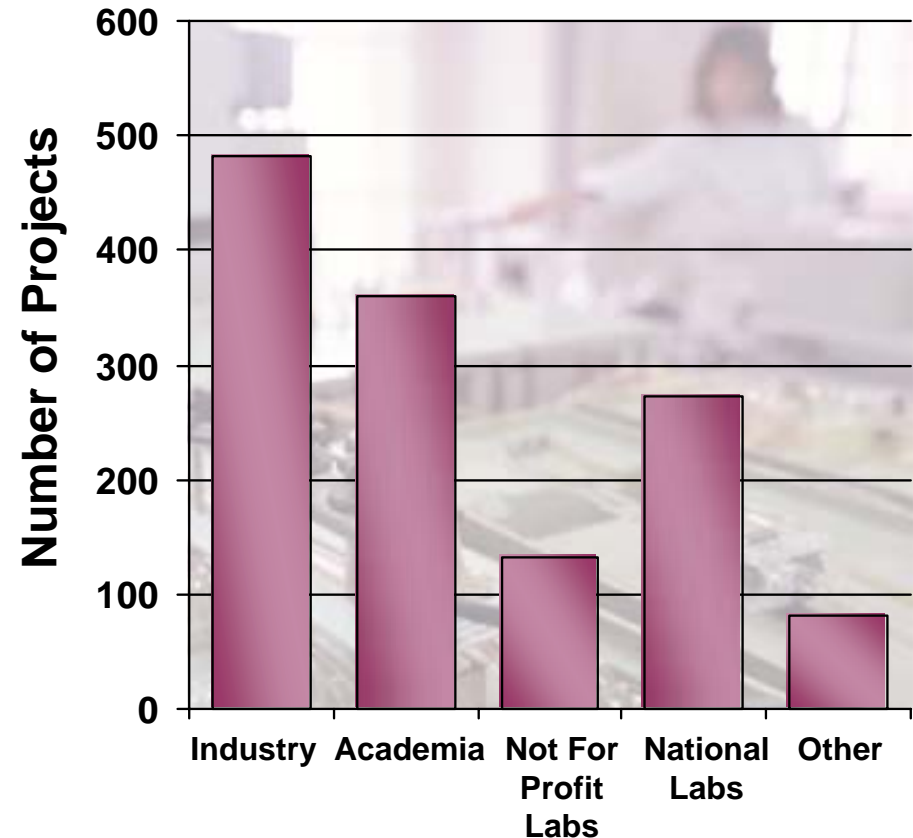
National Energy Technology Laboratory



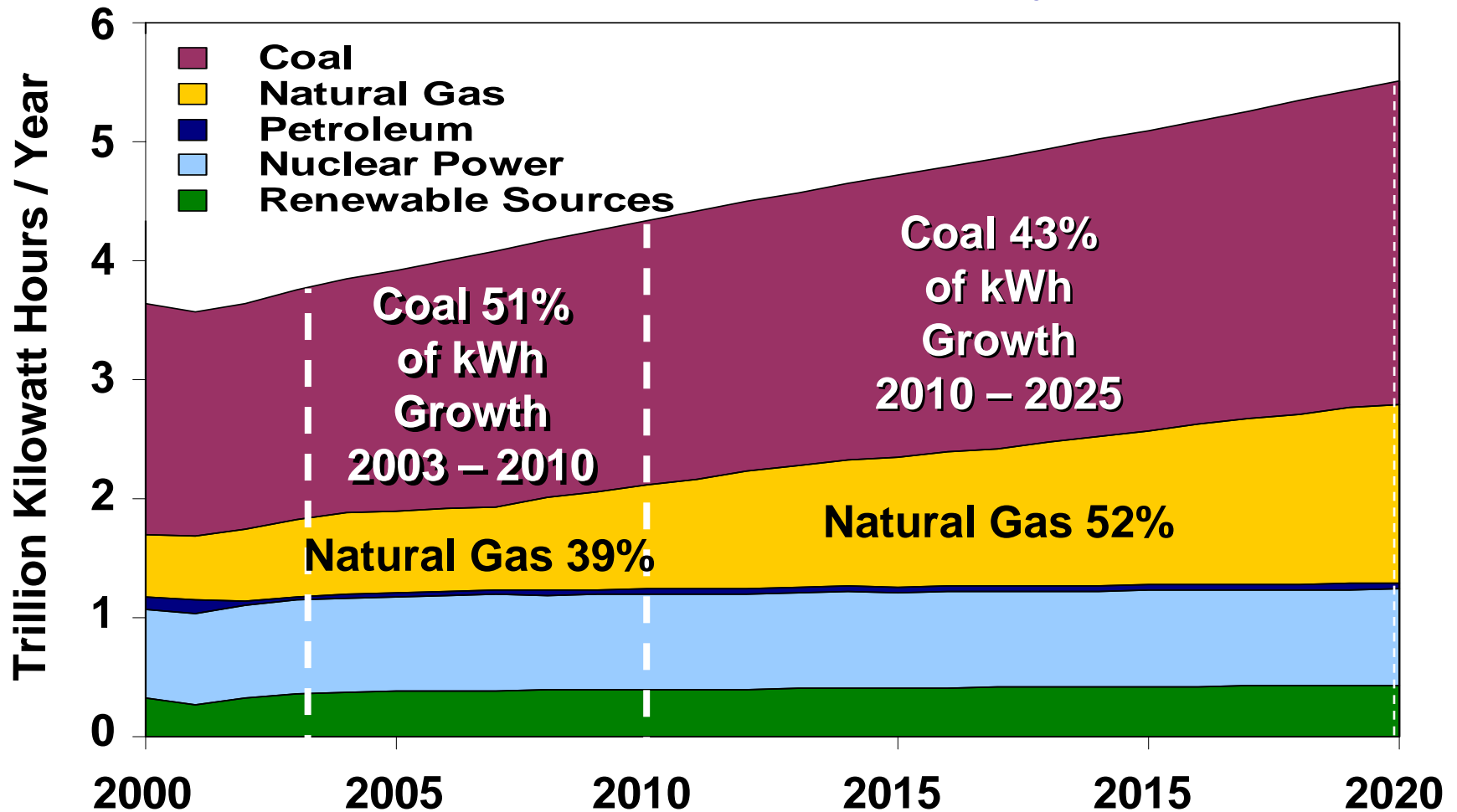
- **One of DOE's 17 national labs**
- **Government owned / operated**
- **Sites in:**
 - Alaska
 - Oklahoma
 - Pennsylvania
 - West Virginia
- **More than 1,100 federal and support contractor employees**

Shape, Fund, and Manage Extramural RD&D

- 1,300 research activities in all 50 states and several foreign countries
- Total award value \$7.3 billion
- Private sector cost-sharing of \$3.6 billion
 - Leverages DOE funding
 - Ensures relevance
 - Accomplishes mission through commercialization



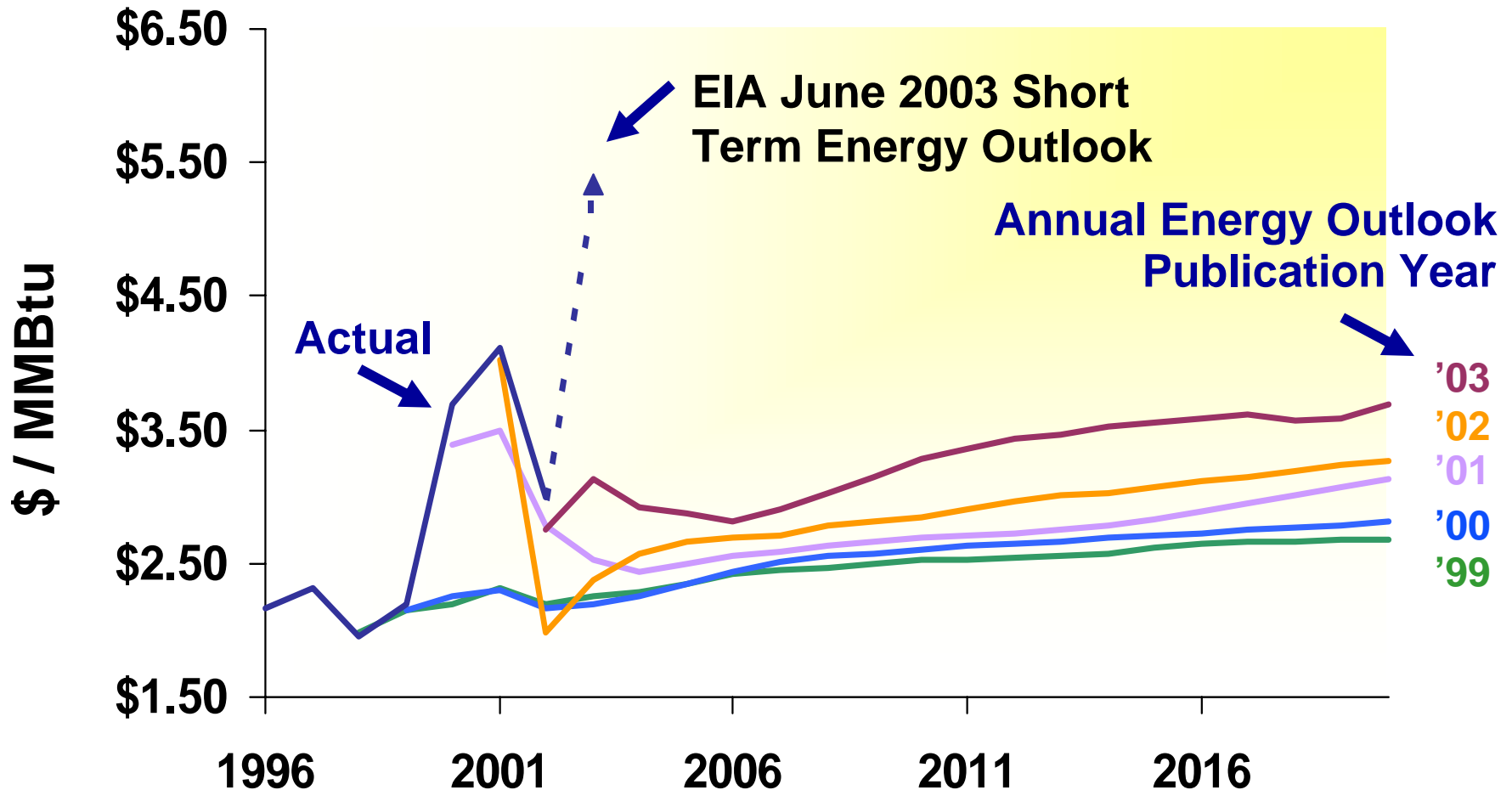
Fuel Mix for Electricity



Coal Expected to Provide 30% More Incremental kWhs Than Gas — 2003 to 2010 — Despite Few Additions



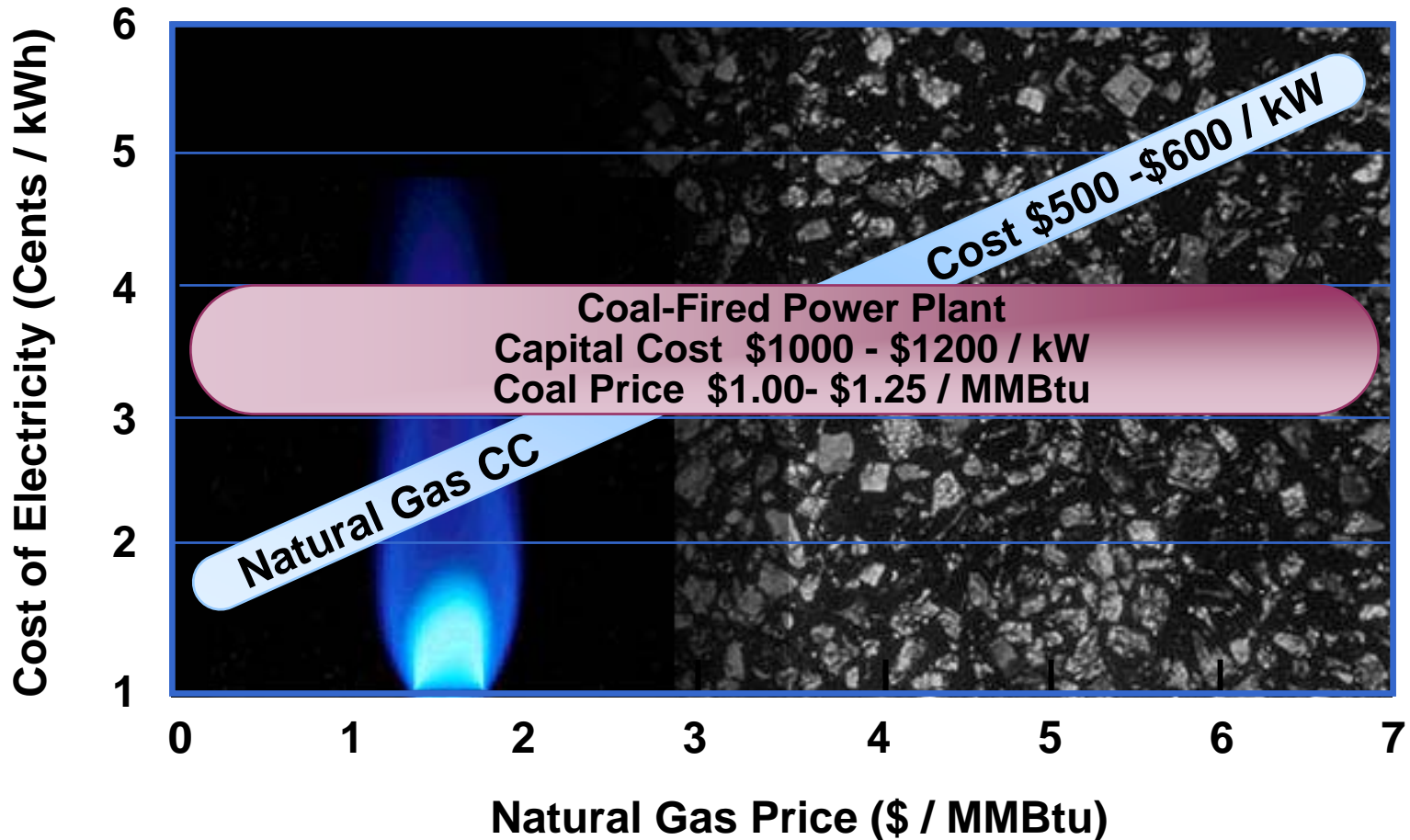
Natural Gas at What Price?



Growing Belief in New Price Plateau at \$4–5 / MMBtu

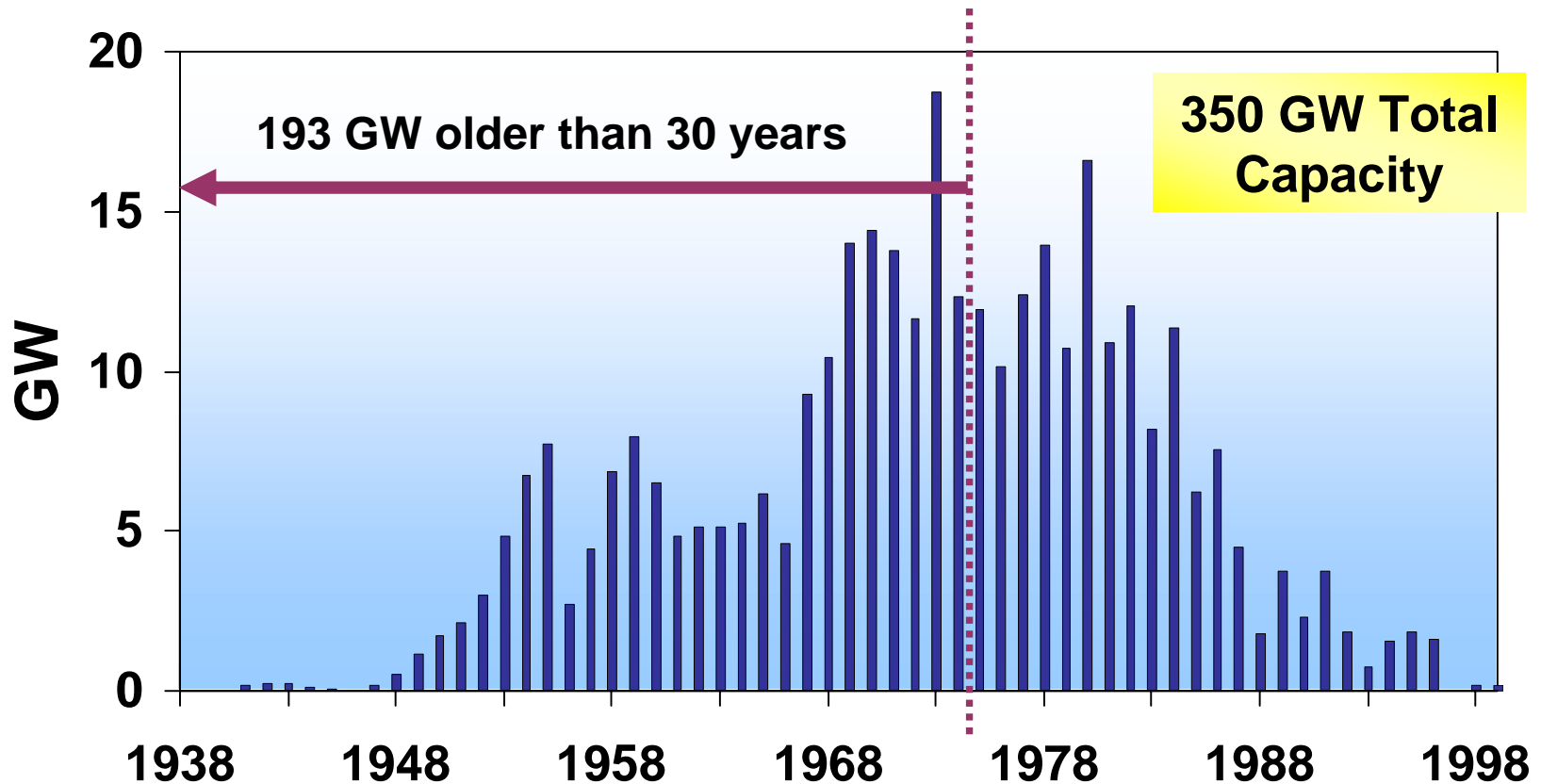


Coal Technologies are Cost Competitive



North American Coal Units

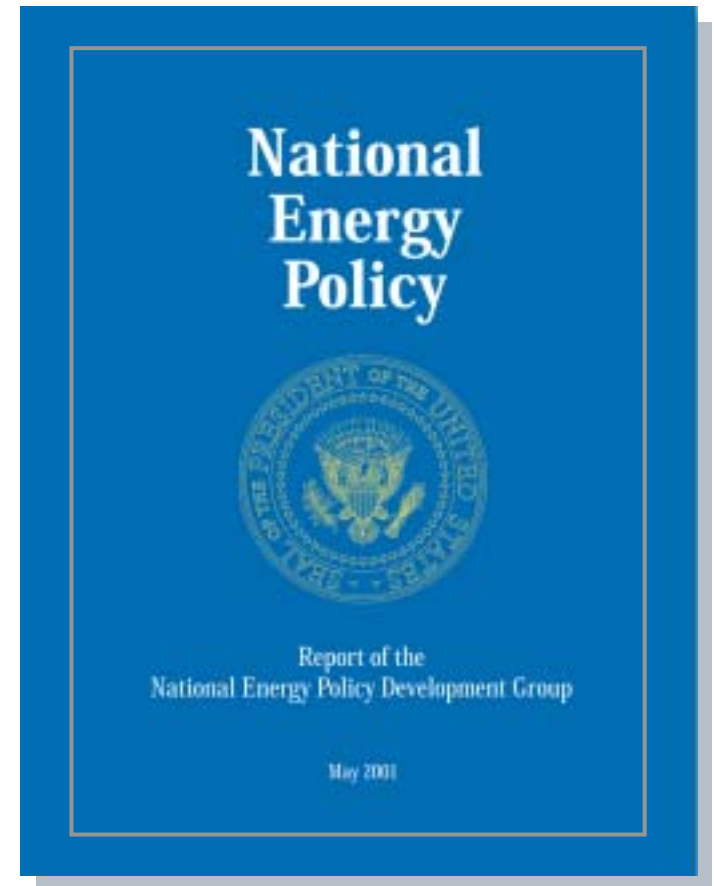
First Year of Operation



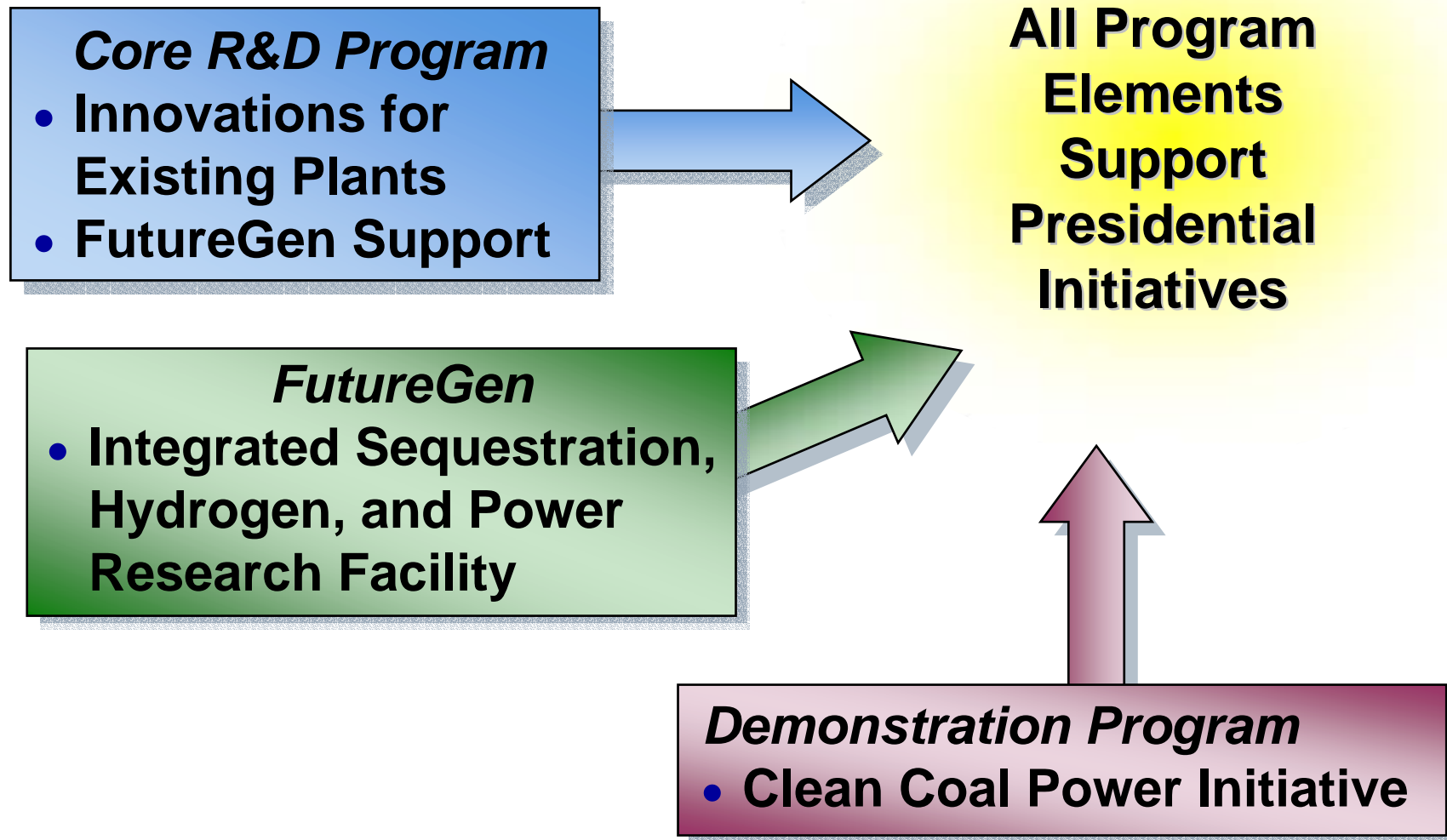
Many coal plants will need to be replaced or repowered starting in 2020

National Energy Policy

- Increasing America's domestic energy supplies
- Protecting America's environment
- Ensuring a comprehensive delivery system
- Enhancing national energy security



Elements of Coal & Power Program



Coal Power Program Roadmap

Addresses Near- and Long-range Needs

- **Short-term: existing fleet**

- Cost-effective environmental control technologies to comply with current and emerging regulations

- **Long-term: future energy plants**

- Near-zero emissions power and clean fuels plants with CO₂ management capability



Can be found on CURC website

www.coal.org

Coal Power Program Roadmap

New Plant Performance Targets

(Represents best integrated plant technology capability)

	Reference Plant	2010	2020 Vision 21
Air Emissions	98% SO ₂ removal	99%	>99%
	0.15 lb/10 ⁶ Btu NO _x	0.05 lb/10 ⁶ Btu	<0.01 lb/10 ⁶ Btu
	0.01 lb/10 ⁶ Btu Particulate Matter	0.005 lb/10 ⁶ Btu	0.002 lb/10 ⁶ Btu
	Mercury (Hg)	90% removal	95% removal
By-Product Utilization	30%	50%	near 100%
Plant Efficiency (HHV)	40%	45-50%	50-60%



Coal Power Program Roadmap

New Plant Performance Targets¹

(Represents best integrated plant technology capability)

	Reference Plant	2010	2020 Vision 21
Availability⁽³⁾	>80%	>85%	≥90%
Plant Capital Cost⁽²⁾ \$/kW	1000 – 1300	900 – 1000	800 – 900
Cost of Electricity⁽⁴⁾ ¢/kWh	3.5	3.0 - 3.2	<3.0

- (1) Targets are w/o carbon capture and sequestration and reflect current cooling tower technology for water use
- (2) Range reflects performance projected for different plant technologies that will achieve environmental performance and energy cost targets
- (3) Percent of time capable of generating power (ref. North American Electric Reliability Council)
- (4) Bus-bar cost-of-electricity in today's dollars; Reference plant based on \$1000/kW capital cost, \$1.20/10⁶ Btu coal cost



Innovations for Existing Plants

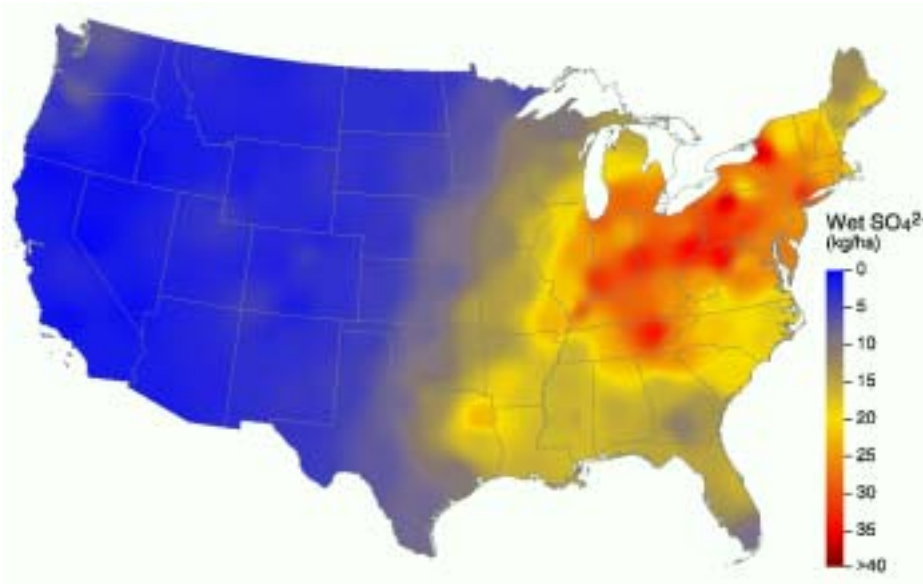
- **Develop affordable environmental control technologies for existing coal plants**
 - Mercury control
 - NO_x control
 - PM 2.5
 - Air quality research
 - Coal byproducts
 - Water management
- **Provide quality technical data for policy makers**



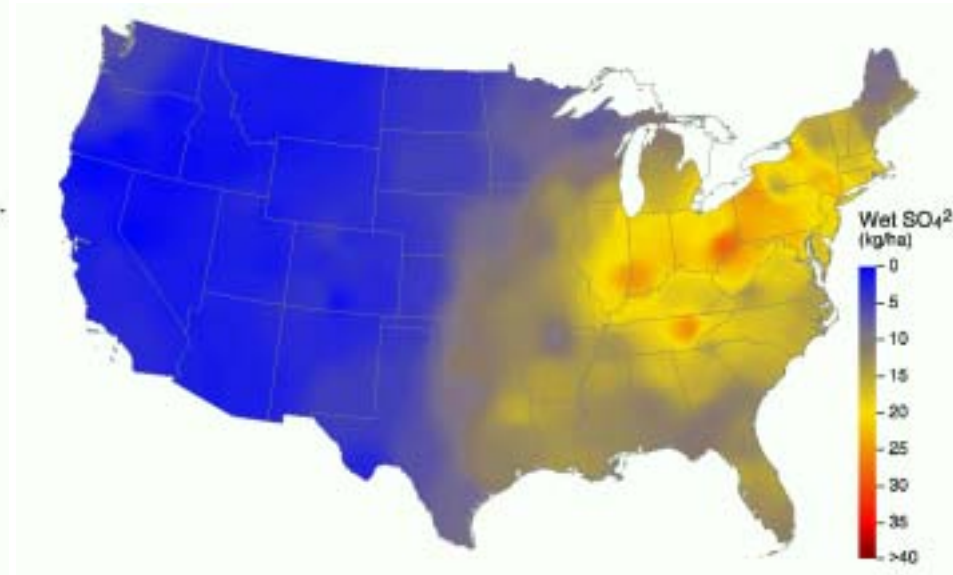
Success: Cleaner Air

Reduction in Wet Sulfate Deposition

1989 - 1991



1998-2000



Acid rain reduced as much as 30% in acid-sensitive ecosystems

Capturing Mercury Is Difficult!

Hypothetical Example

- Dome filled with 30 billion ping-pong balls
- 30 black “mercury” balls
- Find and remove 27 black balls for 90% Hg capture

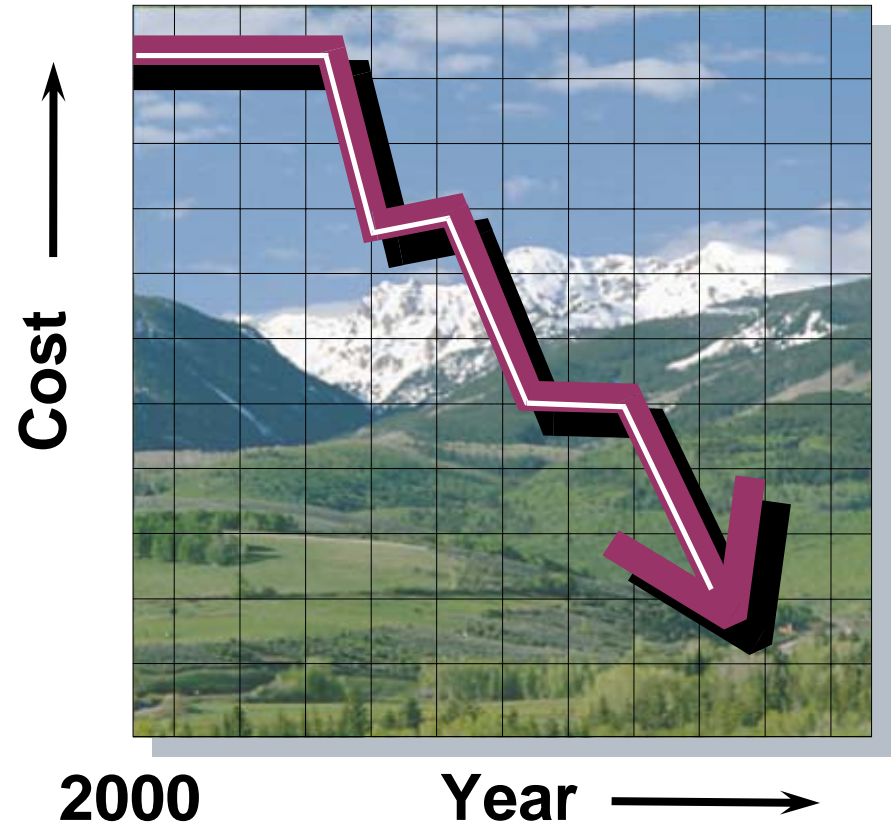
*Houston
Astrodome*



DOE Mercury Control Program Goals

Have technologies ready for commercial demonstration:

- By 2005, reduce emissions 50-70%
- By 2010, reduce emissions by 90%
- Cost 25-50% less than current estimates



Baseline Costs: \$50,000 – \$70,000 / lb Hg Removed

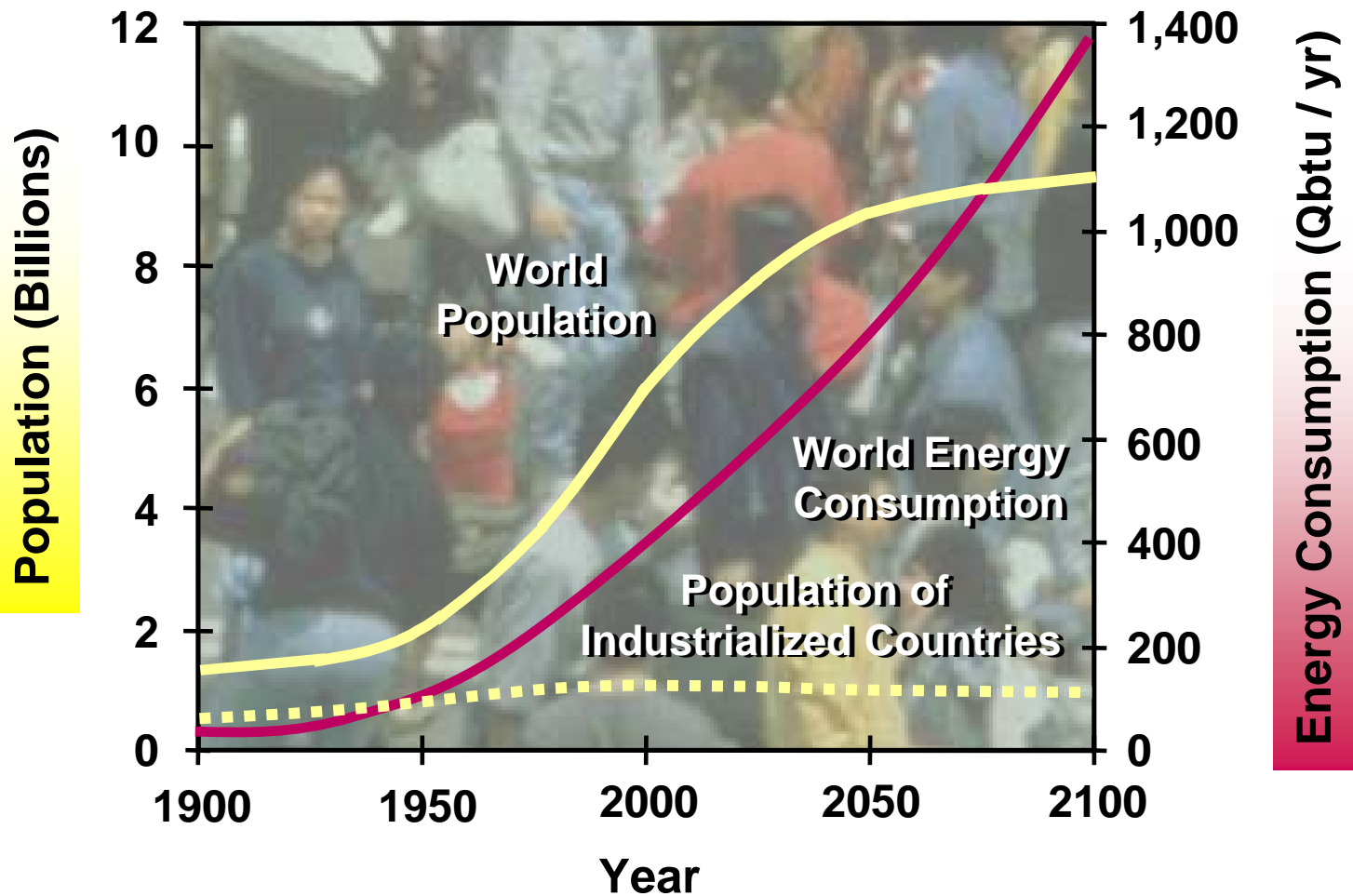
Global Climate Change: Fact or Fiction?

It Probably Doesn't Matter — The Issue Is Here to Stay

- **Science unlikely to provide unequivocal causality answer**
- **Governments and markets likely to act on their perception of the science**
- **Corporate boards likely to evaluate potential risks / benefits of climate change**



World Energy Demand Growing

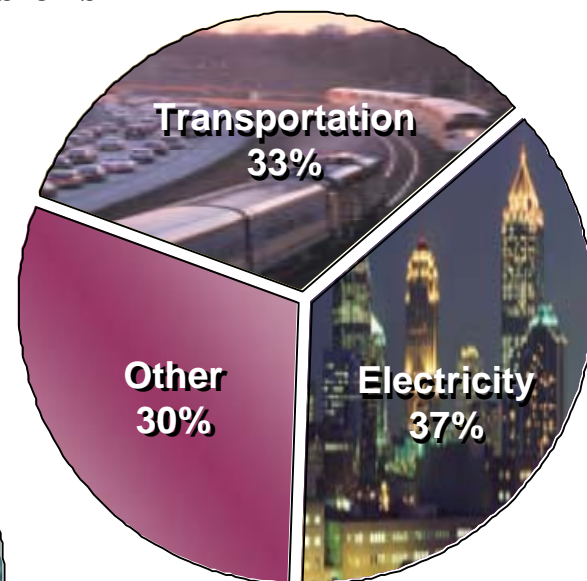
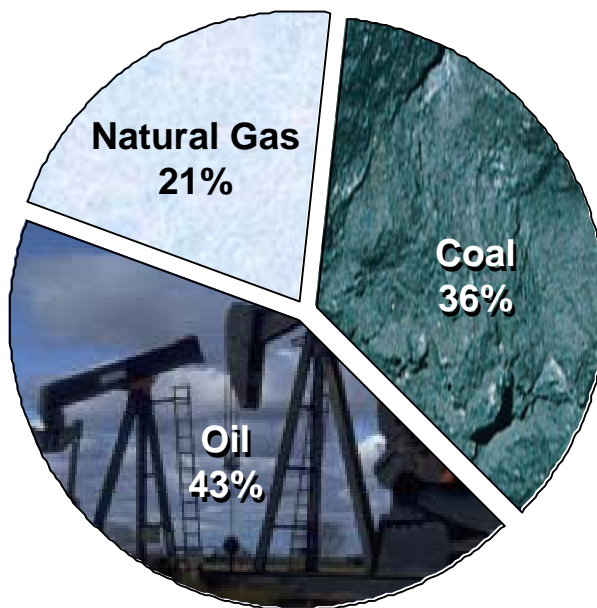
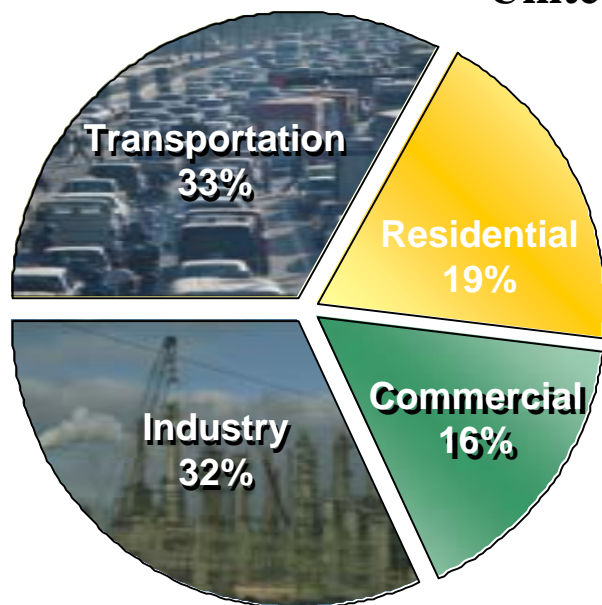


Population Projections: United Nations "Long-Range World
Population Projections: Based on the 1998 Revision"

Energy Projections: "Global Energy Perspectives" ITASA / WEC

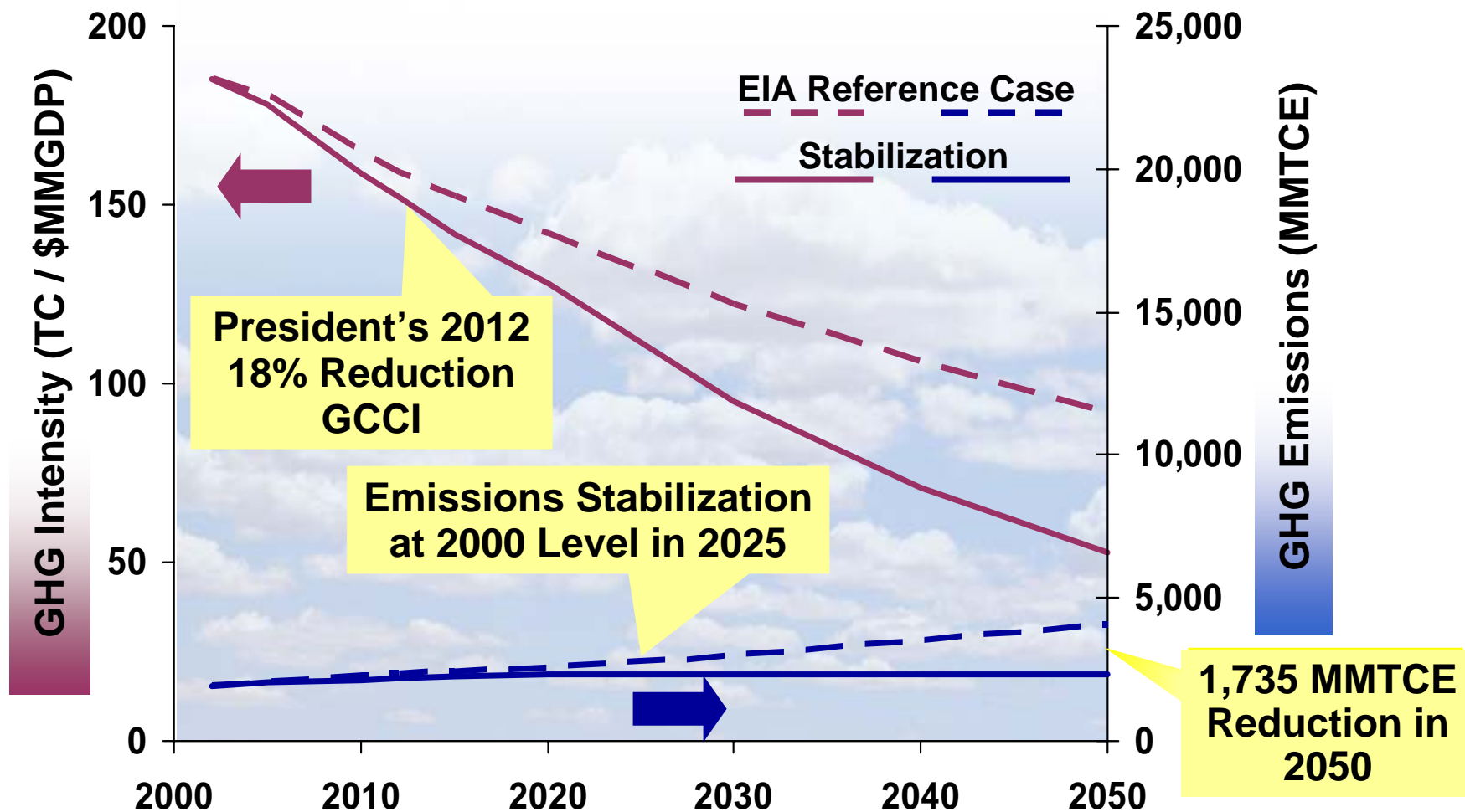
All Fossil Fuels & Energy Sectors Contribute CO₂ Emissions

United States Carbon Dioxide Emissions
(By Source & Sector)



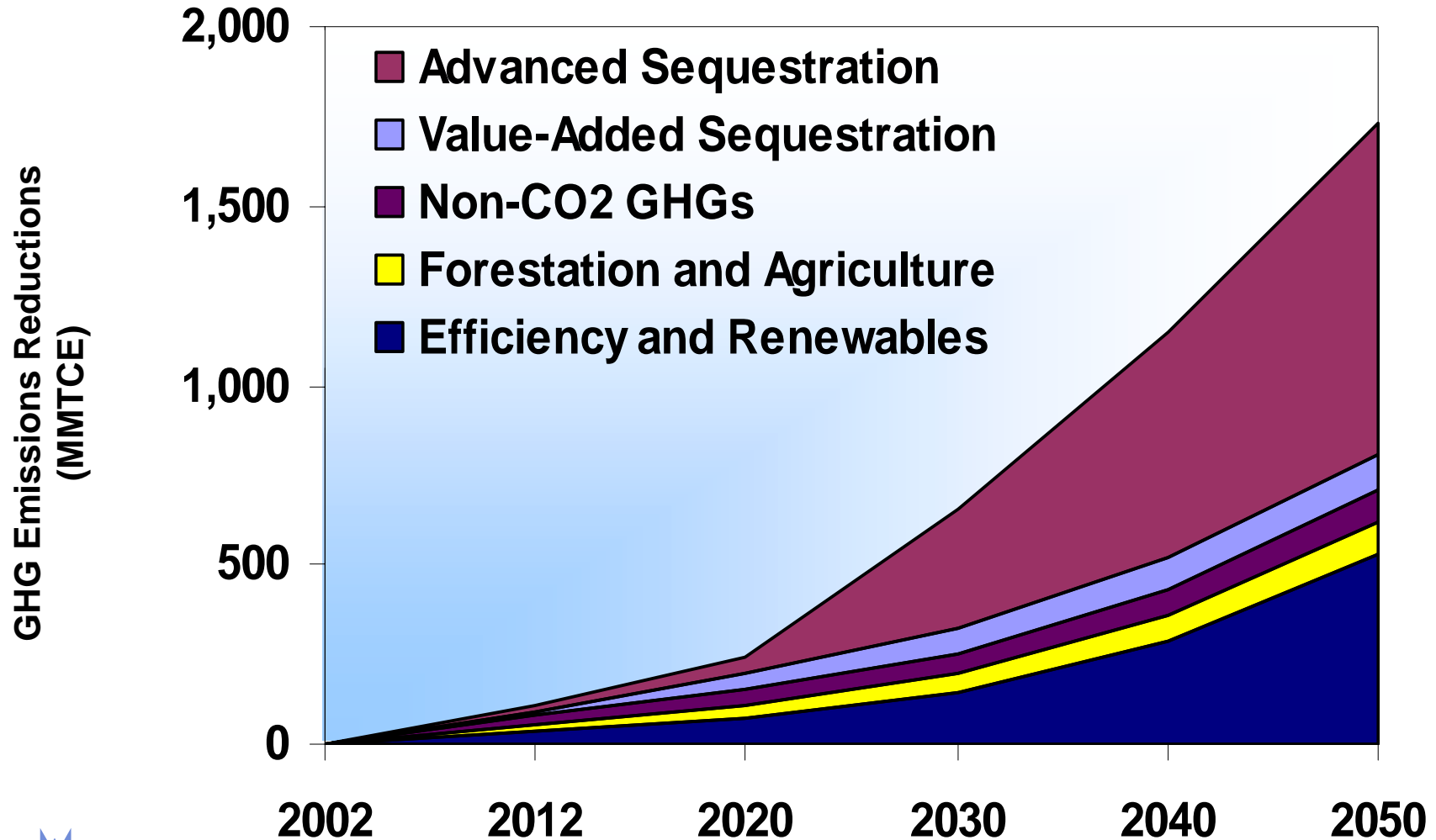
Possible Pathway to Emissions Stabilization

A Significant Undertaking



Sequestration = Stabilization

Plausible Scenario to Stop GHG Emissions Growth



EIA Annual Energy Outlook 2002; EPA special studies;
DOE/FE/NETL Sequestration Benefits Model



Approaches to Sequester Carbon

Capture and Storage



**Unmineable
Coal Seams**

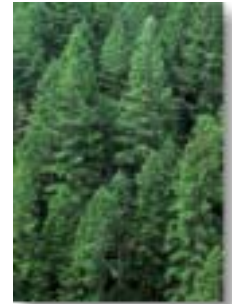


**Deep Ocean
Injection**



**Depleted Oil /
Gas Wells,
Saline Reservoirs**

Enhance Natural Processes



Forestation

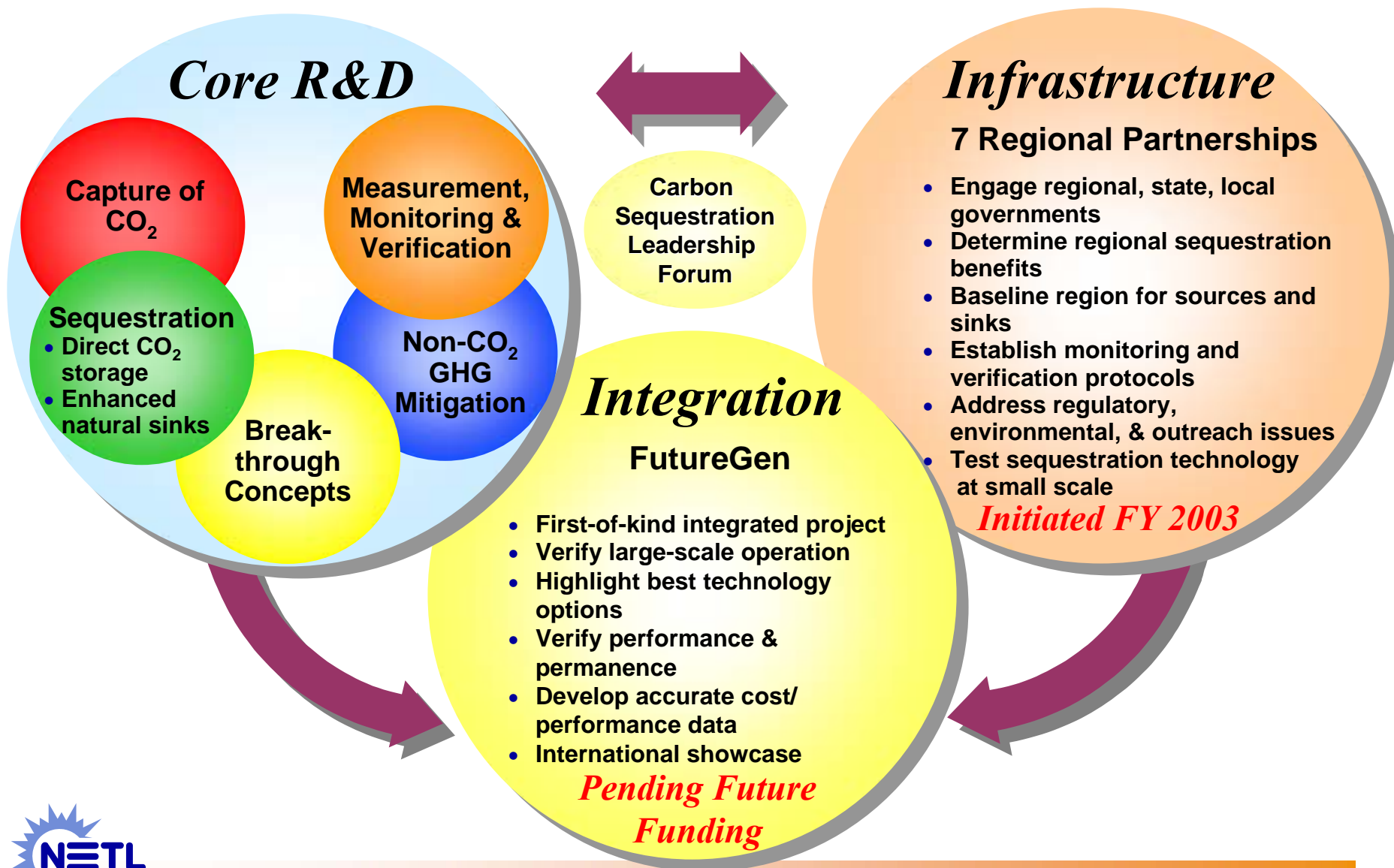


**Iron or Nitrogen
Fertilization of
Ocean**



**Enhanced
Photosynthesis**

Carbon Sequestration Program Structure



A Vision for 2020

Putting the Pieces Together



Fuel Cells



***Zero-Emission
Plants***



**Carbon
Sequestration**



**Gasification with
Cleanup Separation**



Optimized Turbines



**System
Integration**

Why Integrated Gasification Combined Cycle?



- Fuel and product flexibility
- Environmentally superior
- Sequestration ready
- High efficiency

Producing concentrated stream of CO₂ at high pressure

- Improves sequestration economics
- Reduces efficiency penalty

IGCC Technology in Early Commercialization

U.S. Plants in CCT Program

- **Wabash River**
 - 1996 Powerplant of Year Award*
 - Achieved 95% availability
- **Tampa Electric**
 - 1997 Powerplant of Year Award*
 - First dispatch power generator

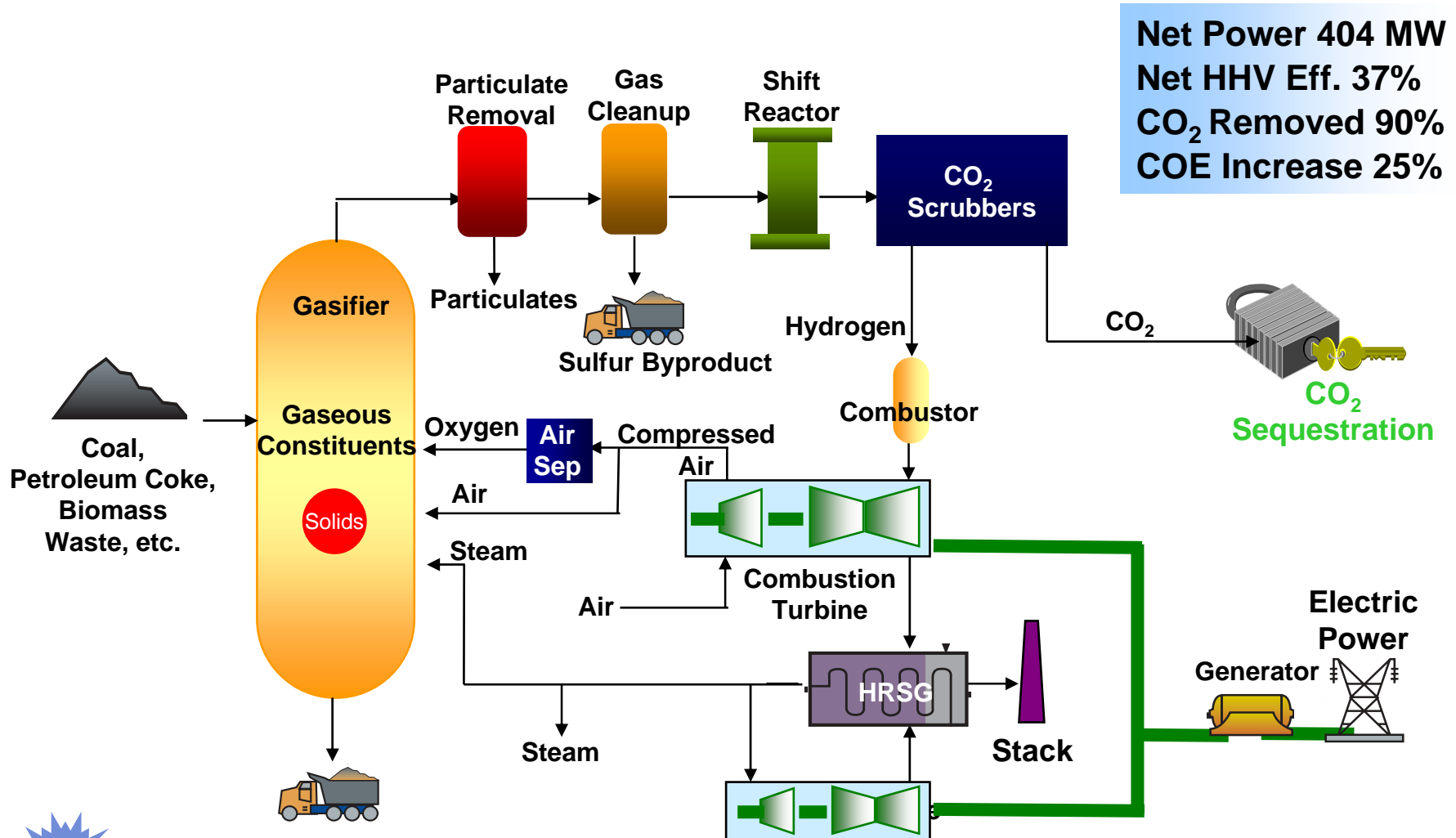


Nation's First Commercial-Scale IGCC Plants, Each Achieving
> 95% Sulfur Removal
≥ 90% NO_x Reductions



Near-Term CO₂ Scrubbed IGCC Plant

EPRI / Parsons / DOE Study



Technology Hurdles

- **Gasification – Reliability and performance**
- **Gas Cleaning – Deep cleaning expensive and inefficient**
- **Air Separation – Costly**
- **Hydrogen Separation – Costly and inefficient**
- **Co-Production – Improves economics**

Gasification Technologies Program

Oxygen Separation Projects

Air Products

- Cerametec
- Texaco
- McDermott
- Eltron Research
- Penn State University
- University of Pennsylvania
- Concept NREC

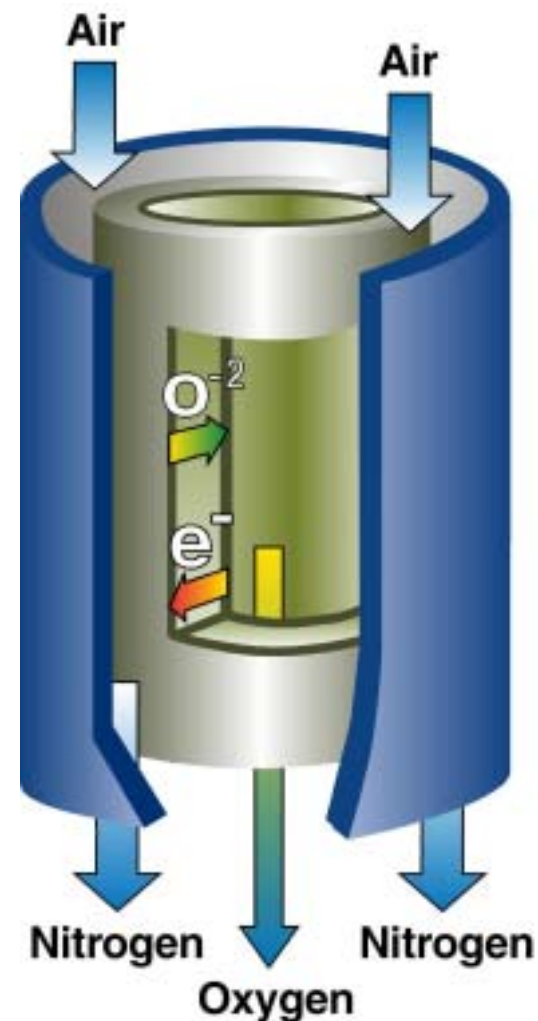
Develop cost effective ion transport membrane for oxygen separation (ITM)

Planar configuration

Praxair (with Consortium)

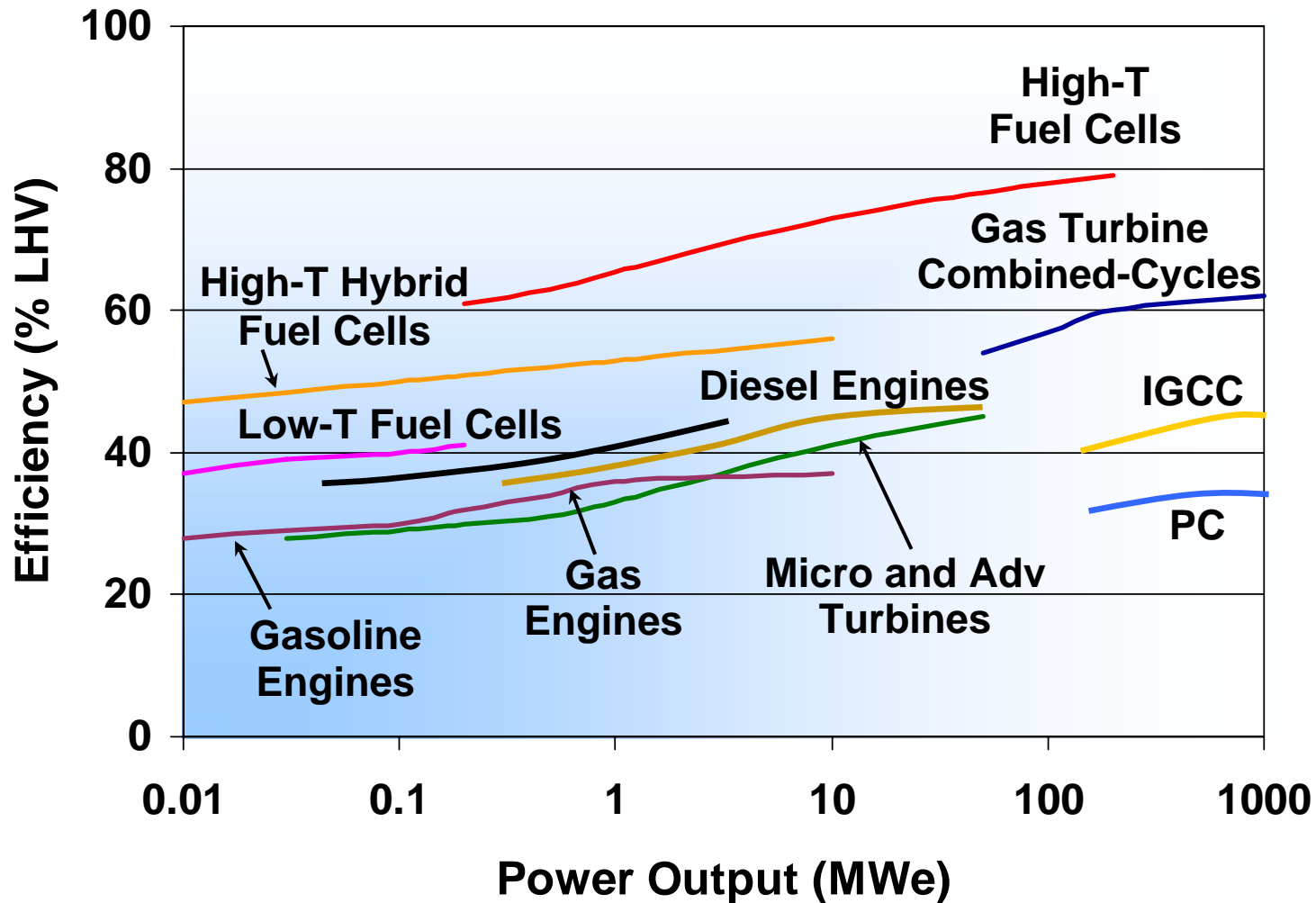
Develop cost effective oxygen separation membranes (OTM)

Tubular configuration



Nothing Matches Fuel Cell Efficiency

Transportation and Stationary Power



Gas Engine - GRI
Diesel Engine - California Advanced Reciprocating Internal
Combustion Engines Collaborative, Workshop Proceedings, July 2001

Fuel Cells Are Real!

Phosphoric Acid

- IFC
- 220 200-kW units
- > 40% efficiency
- > Six “9’s” reliability
- \$4,500/kW



Molten Carbonate

- Fuel Cell Energy
- 50 MW/year manufacturing facility
- 10 million kWh generated at customer sites with MW and sub MW units



3-10 kW Solid State Fuel Cells for Multiple Applications



2005 Beta Prototype

- **\$800/kW**
 - Premium power
 - Auxiliary power in long-haul trucks
 - Military

2010 Product

- **\$400/kW**
 - Residential
 - Industrial CHP



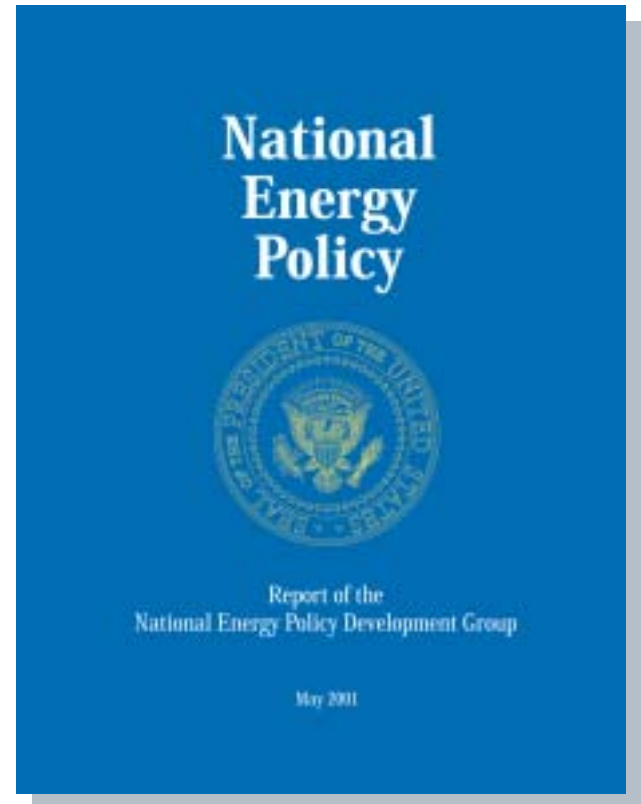
2015

- Vision 21 power plants
- Hybrid systems

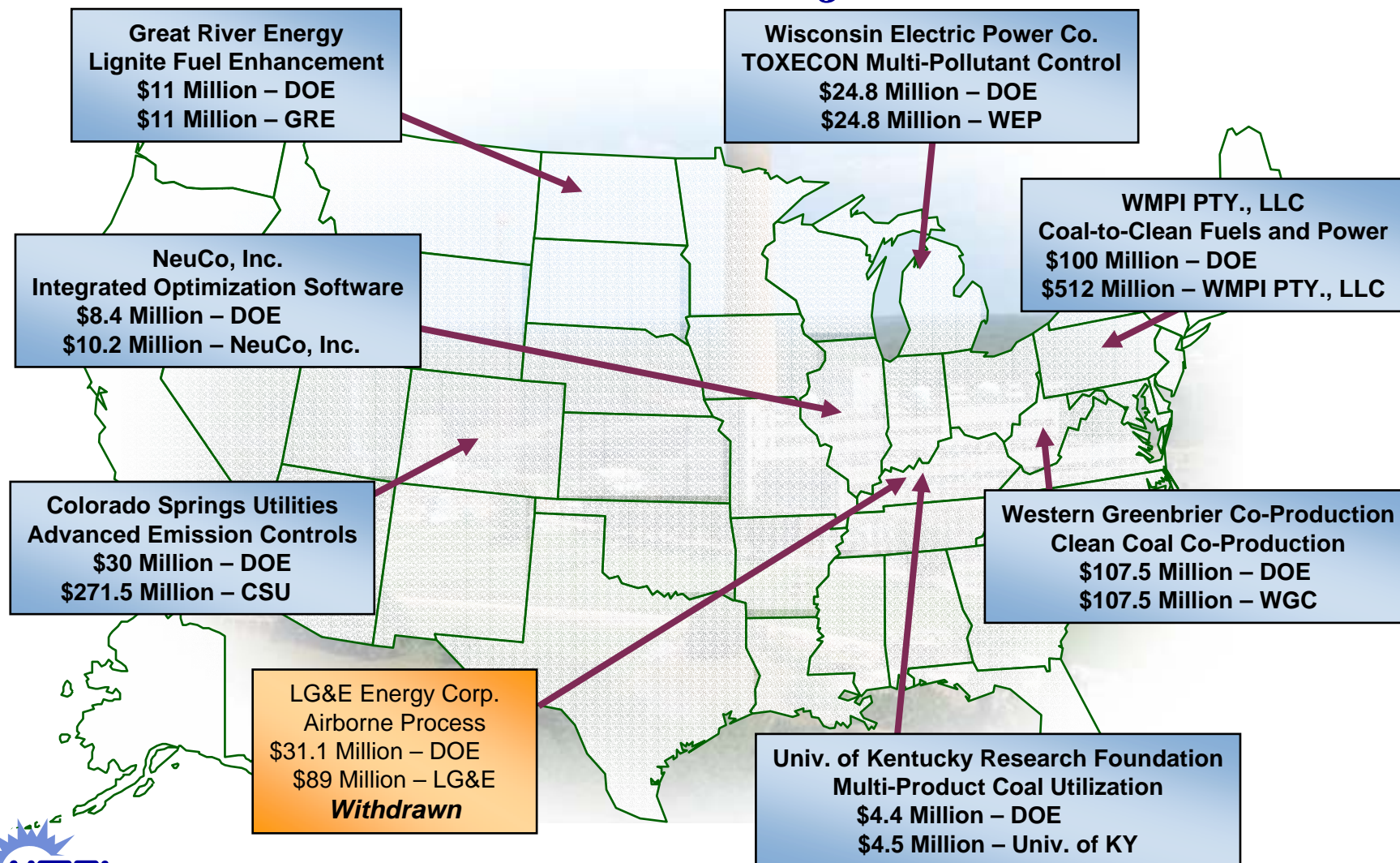


Clean Coal Power Initiative

- Implemented NEP recommendation to increase investment in clean coal technology
- \$2 billion over 10 years starting in FY 02
 - Anticipates series of competitive solicitations
 - Industry cost share of at least 50%

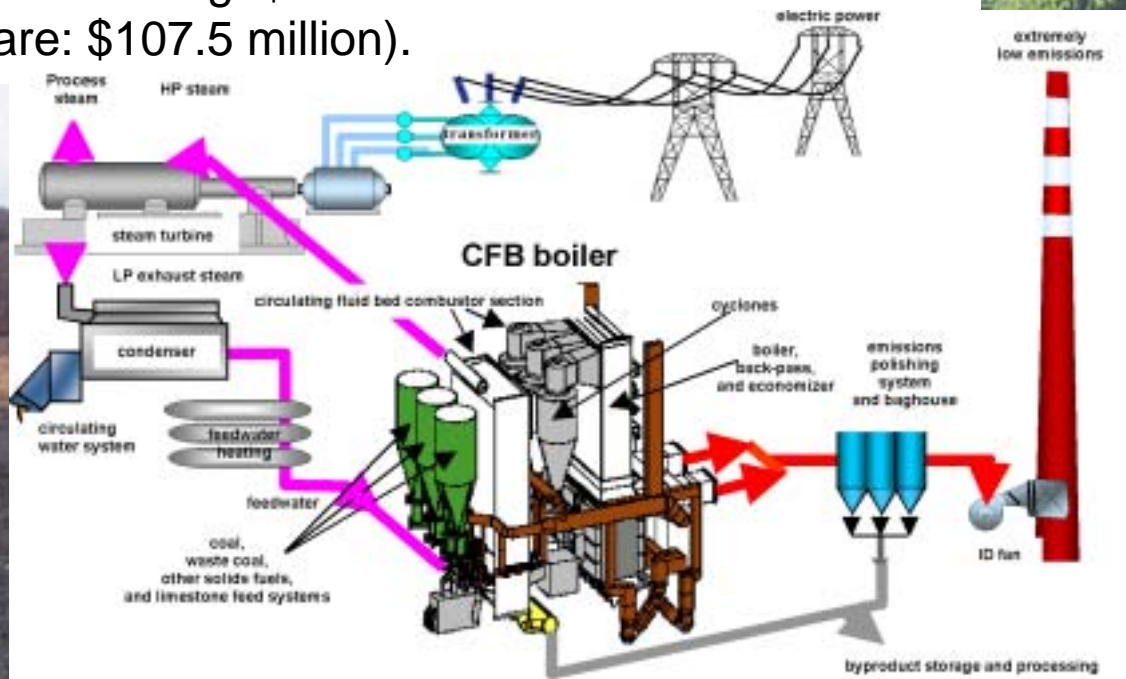


Clean Coal Power Initiative (CCPI) – Round 1 Projects



Western Greenbriar Co-Generation, LLC

- Anchor tenant in a proposed environmentally balanced industrial “Eco Park”; remediation model for State/Local Governments.
- 85 MW waste-coal to clean energy circulating fluid bed combustor with advanced multi-pollutant control system.
- Total project funding: \$215 million (DOE Share: \$107.5 million).



A CCPI Round 1 Project



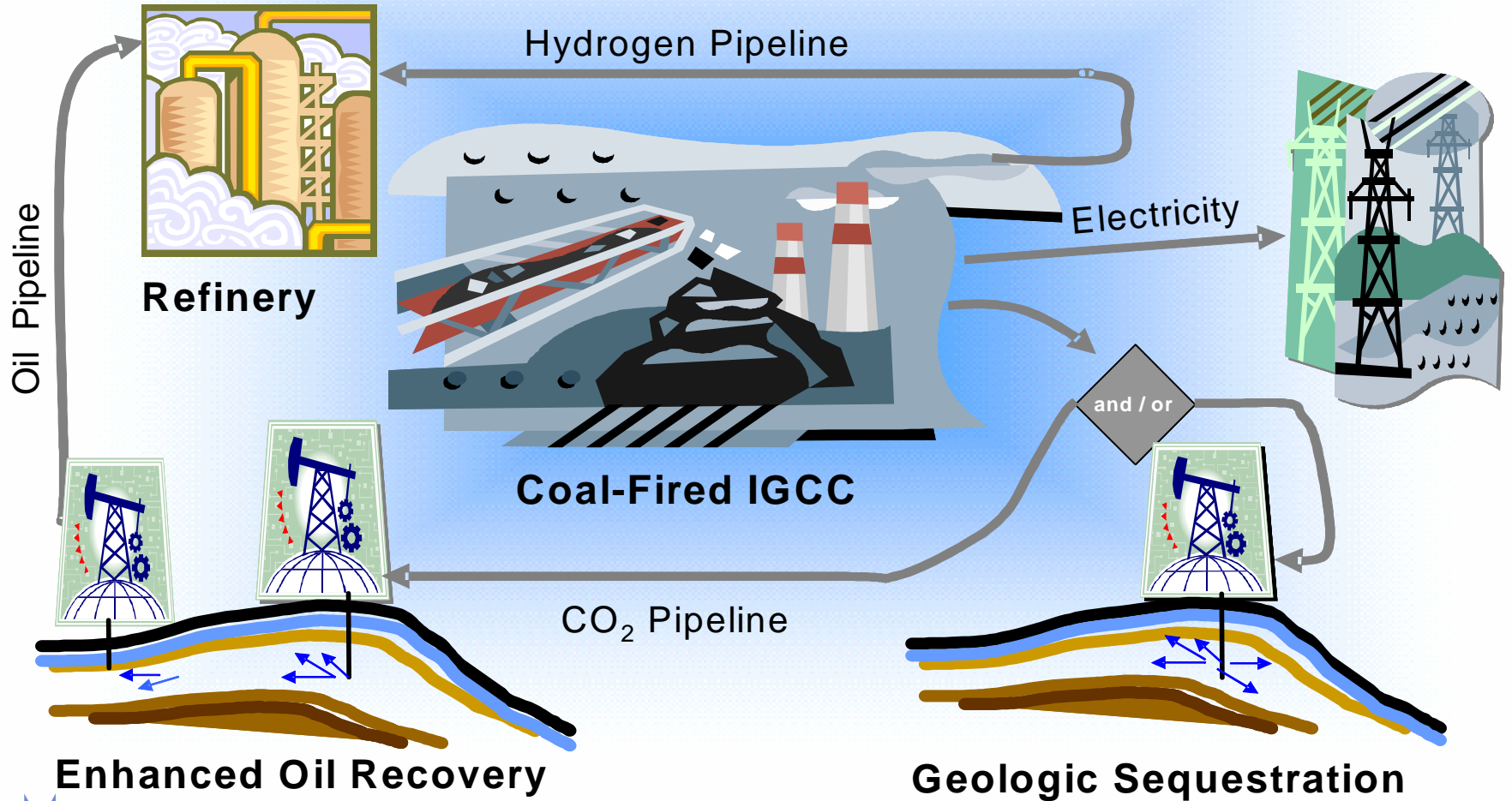
FutureGen: A Presidential Initiative

One-billion-dollar, 10-year demonstration project to create world's first coal-based, zero-emission electricity and hydrogen plant
President Bush, February 27, 2003

- Produce electricity and hydrogen from coal using advanced technology
- Emit virtually no air pollutants
- Capture and permanently sequester CO₂



FutureGen Concept



Mining is Critical to Quality of Life

Every American Born Will Use...



11.7 Tons Clays	15.2 Tons Salt
1,925 lbs. Copper	1,001 lbs. Zinc
1.8 Troy oz. Gold	850 Tons Stone, Sand, Gravel
295 Tons Coal	83,890 Gallons Petroleum
13.9 Tons Phosphate	34.4 Tons Cement
3 Tons Aluminum	34.5 Tons Other Minerals and Metals
1,078 lbs. Lead	6 million cu. ft. Natural Gas
21.3 Tons Iron Ore	

1,875 tons of minerals, metals, and fuels in a lifetime



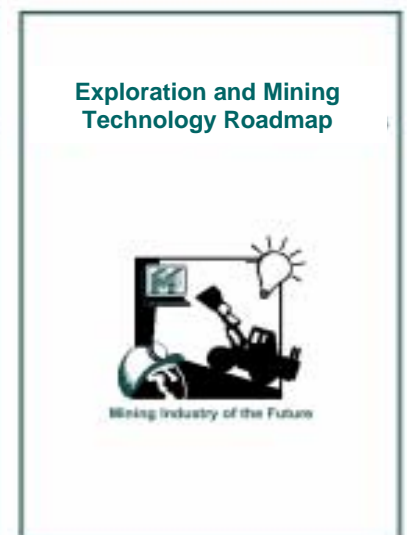
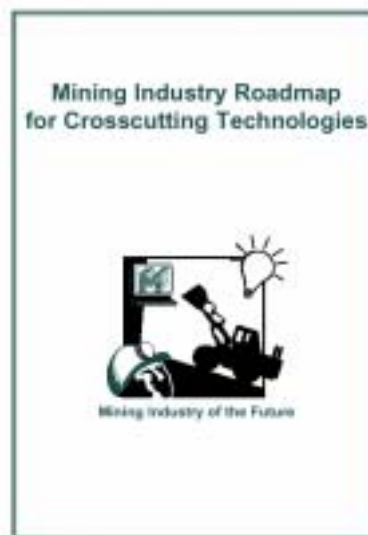
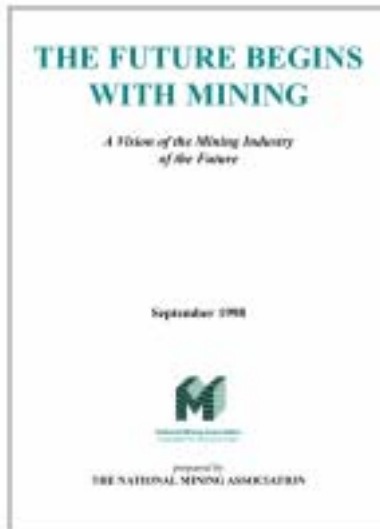
Mining Industry Vision and Roadmaps

Vision

- The Future Begins with Mining (9/1998)

Targeted Roadmaps

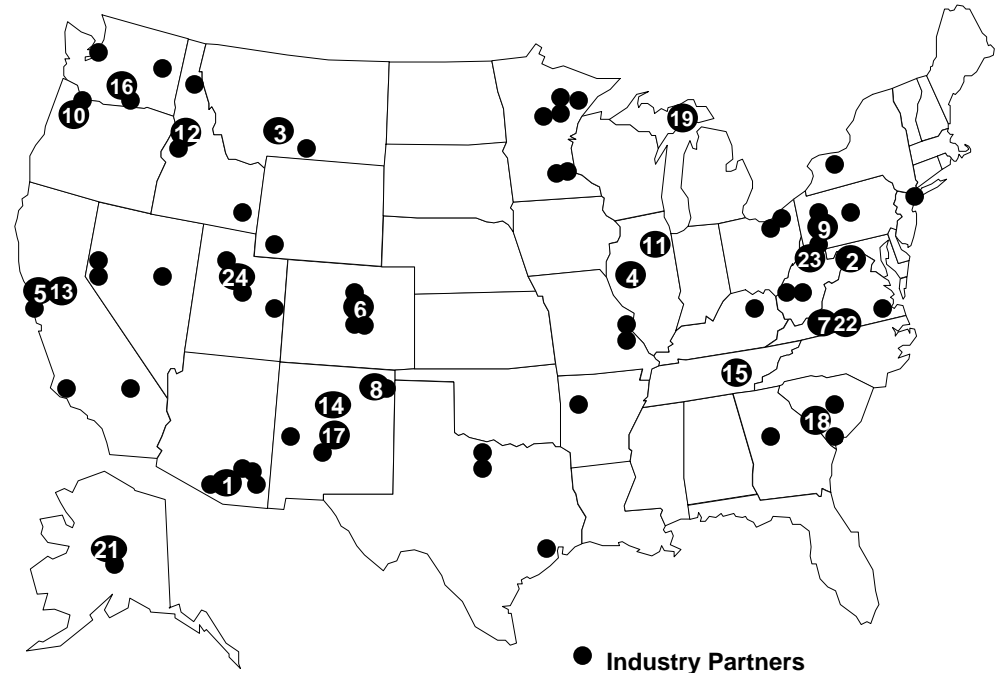
- Crosscutting Technologies Roadmap (2/1999)
- Mineral Processing Technologies Roadmap (9/2000)
- Exploration and Mining Technologies Roadmap (9/2002)



Current Mining Research Partners

Primary Research Performers

1. Advanced Ceramics Research, Inc.
2. Advanced Power Technologies, Inc.
3. AdvR, Inc.
4. Caterpillar Inc.
5. Electromagnetic Instruments, Inc.
6. Fuel Cell Propulsion Institute
7. Minerals and Coal Technologies Inc.
8. Stolar Horizon, Incorporated
9. Transtek, Inc.
10. Albany Research Center
11. Argonne National Laboratory
12. Idaho National Engineering and Environmental Laboratory
13. Lawrence Berkeley National Laboratory
14. Los Alamos National Laboratory
15. Oak Ridge National Laboratory
16. Pacific Northwest National Laboratory
17. Sandia National Laboratory
18. Savannah River Technology Center
19. Michigan Technological University
20. QRDC
21. University of Alaska
22. Virginia Polytechnic Institute and State University
23. West Virginia University
24. University of Utah

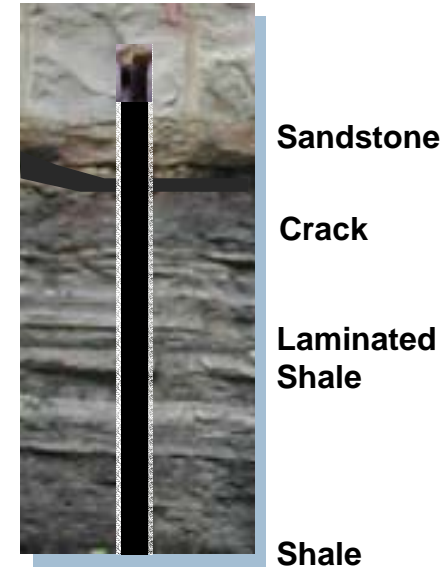


Mining Industry of the Future is currently funding 34 cost shared projects with 151 project partners including 141 from industry and academia.



Computerized Roof Bolt Design System

- Principal Investigator: **Syd Peng- WVU**
- Partners: **CONSOL Energy, Ohio Valley Coal, J. H. Fletcher & Co., Massey Coal Co., Riverton Coal Production Inc., Newmont Mining Co.**
- Project Cost: **\$1,352,338**
 - DOE Share \$563,504



NETL – Science and Technology

- Acid mine drainage science and technology
- Coal by-product science and technology
- Watershed science and management
- Remote sensing (geophysical) and airborne multi-spectral surveying
- Carbon management (geologic sequestration and mine-land reclamation)



Closing Comments

- **Coal must play a key role to secure a healthy economy**
 - Is recognized in Presidential-level initiatives; Clear Skies, Climate Change, FutureGen, Hydrogen, Sequestration
 - Coal can play an important role in a potential future carbon-constrained world
- **Regulatory uncertainty improving**
- **Coal RD&D Roadmap charts challenging but doable path forward**
 - Best ideas needed



Visit Our NETL Website
www.netl.doe.gov

Visit Our OCES Website
www.netl.doe.gov/coalpower/

NATIONAL ENERGY TECHNOLOGY LABORATORY
 United States Department of Energy

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February 06, 2003

What's New
 Business
 Career Ops
 Events
 Publications
 Technologies
 On-site R&D
 People
 Maps
 Coal Science
 ISO14001
 Newsroom

Energy Statement
TOP NEWS STORIES

DOE Names Winners of Clean Coal Competition
\$1.3 Billion of Projects Aimed at Clear Skies, Climate Change & Coal Waste Cleanup
 The Department of Energy has named the first winners in President Bush's **Clean Coal Power Initiative**. The eight projects are valued at more than \$1.3 billion and include new technologies to reduce air pollutants, boost power plant efficiencies, and extract energy from coal waste piles. [Read More!](#)

Experimental Fiber Optic Cables To Warn of Potential Pipeline Damage Tests Begin of an "Early Warning" System To Prevent Damage to Natural Gas Pipelines
 Technicians in a joint DOE-industry project have deployed fiber optic cables over a mile of an active gas pipeline in the first test of a new system to detect encroaching construction activity. [Read More!](#)

Gas Upgrading R&D "Success Story"
 A new gas upgrading technology funded by DOE and the Gas Technology Institute moves to market. [Link To G.T.I. Announcement](#)

NEW! DOE AWARDS NEW CONTRACTS TO IMPROVE POWER PLANTS BY:
Recycling Coal Combustion Ash
 A cooperative agreement with Universal Aggregates, LLC calls for a manufacturing plant at the Birchwood Power Facility in King George, Virginia, to turn coal ash into aggregate. [Read More!](#)

Integrating Lower-Cost NOx Controls
 A unique combination of high-tech combustion modifications and sophisticated control systems will be tested on a Kansas coal plant to show how new technology can reduce air emissions and save money. [Read More!](#)

Visit the Homeland Security Energy Infrastructure Website!

SPECIAL ANNOUNCEMENTS

- [Powder River Coal Can Be Rich Source of Natural Gas](#) [PDF]
- [Abraham Announces Plans to Expand Sequestration Program](#)
- [Regional Carbon Sequestration Partnerships Solicitation](#)

BUSINESS SECTORS

- Strategic Center for Natural Gas
- Coal and Env. Systems
- Climate Change Policy Support
- National Petroleum Technology Office
- Env. Technologies & Business Excellence
- Homeland Security Energy Infrastructure

NATIONAL ENERGY TECHNOLOGY LABORATORY
OFFICE OF COAL & ENVIRONMENTAL SYSTEMS

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Office of Coal & Environmental Systems

Welcome to NETL's **Office of Coal and Environmental Systems** webpage. From promoting gasification and combustion technologies, to funding and fostering carbon sequestration and advanced research, we take the steps necessary to ensure coal is sustained as a clean and affordable energy supply.

Through this website, we hope to answer your questions about using coal as a reliable, stable, and sustainable source for electric power. We will share with you the technologies in place now to make this a reality, and the planning, funding, and development efforts to make tomorrow's technologies a reality, today.

[Tracking New Coal-Fired Power Plants](#) (PDF-445KB)

[What's New](#) | [Business](#) | [Events](#) | [Publications](#) | [Technology](#) | [On-site R&D](#) | [People](#) | [Maps](#) | [Coal Science](#) | [NETL TV](#) | [Newsroom](#) | [Welcome](#) | [Search](#) | [Site Index](#) | [Links](#) | [Feedback](#) | [Home](#)

2002 National Energy Technology Laboratory
 U.S. Department of Energy

Playing a central planning and coordination role in ensuring that coal is sustained as an abundant, affordable, and acceptable resource for satisfying our country's need for energy, now and well into the future.

Advanced Research
Carbon Sequestration
Clean Coal Power Initiative (CCPI)
Combustion Technologies
Environmental & Water Resources
Gasification Technologies
Mining Industry of the Future
Vision 21

BUSINESS SECTORS

- Strategic Center for Natural Gas
- Coal and Env. Systems
- Climate Change Policy Support
- National Petroleum Technology Office
- Env. Technologies & Business Excellence
- Homeland Security Energy Infrastructure

